PB-215 398

TREATMENT OF BEET SUGAR WASTES

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Cincinnati, Ohio

1954

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Presented at the First
Ontario Industrial Waste Conference
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TREATMENT OF BEET SUGAR WASTES

The beet sugar industry became established on a paying basis early in the 19th Century when Napoleon's blockade of the British Isles created a sugar shortage on the continent of Europe. The industry is comparatively young in Canada, having been started some fifty years ago. Today production of sucrose from sugar beets is a major chemical industry. In 1952, Canada produced 298,245,300 pounds of beet sugar from 1,028,000 short tons of beets. This represents about one-quarter of Canada's annual sugar consumption. Based on 5-Day BOD, liquid wastes for the Canadian beet sugar industry have been estimated to have a population equivalent potential of 1,400,000.

ORGANIZATION AND OPERATION

Four companies operate seven beet sugar refineries in the Dominion. Refineries are located in the provinces of Alberta, Ontario, Manitoba, and Quebec. In 1952, Alberta with three refineries harvested 46.5 per cent of the beets and Ontario with two refineries processed 33.1 per cent of the total for the Dominion. A Steffen house is located at Raymond, Alberta. It also works molasses from the other two Alberta refineries. The Taber, Alberta and Chatham, Ontario, plants have continuous diffusers. The Raymond and Picture Butte, Alberta refineries use pulp silos whereas the other plants dry the pulp. The season lasts for some ten weeks beginning about October 1 in Alberta and Manitoba and mid-October for Ontario.

DESCRIPTION OF PROCESS

The sugar beet is approximately 75 per cent water and 25 per cent dry solids. The sugar content may be expected to vary between 15 and 17 per cent depending on the season and the region where the beets are grown. The non-sugars are composed of cellulose, nitrogenous compounds, ash, and other organic materials. Process wastes may be expected to contain about 4.6 per cent of the weight of the beet in addition to soil and other extraneous material removed from the beet preparatory to slicing.

Figure 1 is a simplified flow diagram showing basic steps in beet sugar manu-

facture and points in process where liquid wastes are produced. Flowing water in flumes transports beets from storage to the plant. This operation washes most of the soil from the beets and screens are provided to catch beet tops, roots, and other material. The washed beets are sliced into long narrow sections called "cossettes." Extraction of sugar is accomplished in diffusers by counterflow of hot water through the cossettes. The extracted juice is purified by chemical treatment and filtration, and then evaporated to the point where sugar crystals form. Sugar is centrifuged from the syrup, washed, dried, and packaged. The syrup (molasses) may be marketed or diverted to Steffen treatment for more complete extraction of sugar. The spent cossettes constitute high grade stock food and are either stored wet in open silos or are immediately dewatered and bagged.

In the Steffen process, molasses from the third centrifuging is diluted and lime is added under carefully controlled conditions. This lime treatment produces a calcium saccharate precipitate, which is removed from the dilute molasses by filtering. The filtrate is known as Steffen waste. The saccharate cake is diluted to a milk and used for raw juice purification immediately prior to carbonation. Sugar returned in the saccharate cake is recovered by conventional straight house operation. A more detailed statement pertaining to both Steffen and straight house processes as related to wastes has been published (1).

VOLUME AND CHARACTER OF WASTES

Values considered to be representative of the volume and character of beet sugar manufacturing wastes are given in Table I. Cognizance must be taken of differences in process equipment and other pertinent factors in estimating waste volume and character for a given factory. A brief discussion of each of the principal wastes is presented in subsequent paragraphs.

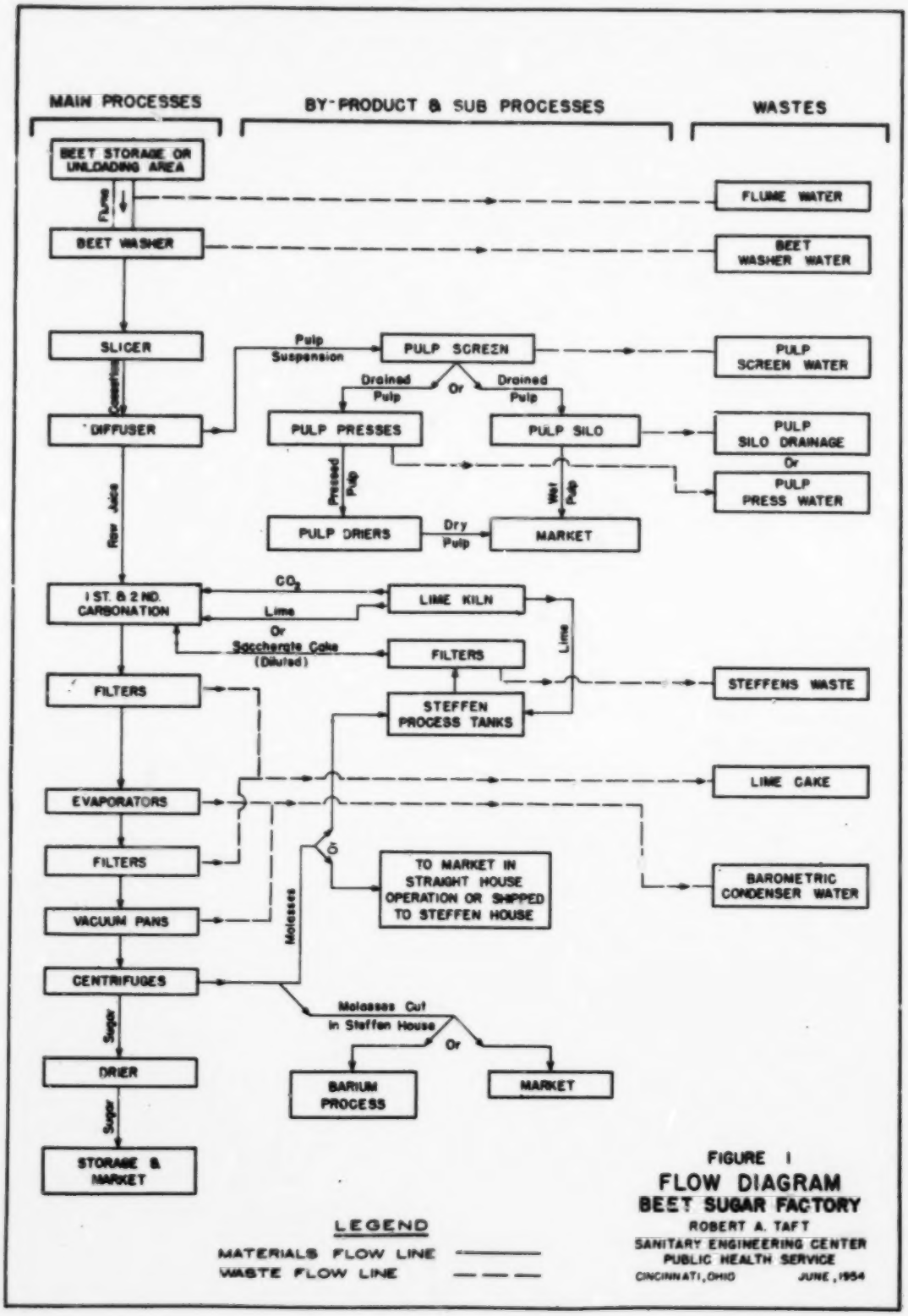

FIGURE 1

FLOW DIAGRAM
BEET SUGAR FACTORY

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CINCINNATI, OHIO

JUNE, 1954

TABLE I. Representative Values of Character and Volume of Beet Sugar Manufacturing Wastes

Waste	Flow, per Ton of Beets (Imp. Gal.)	B.O.D. 5-day, 20°C. (ppm)	Susp. Sol. (ppm)	5-Day B.O.D. per ton of Beets Sliced (lb.)
Flume Water	2,170	210	800-4,300	4.5
Pulp screen water:				
Bottom dump cell-type diffuser	200	980	530	2.0
Side dump cell-type diffuser	1,180	500	620	5.9
Continuous diffuser[1]	333	910	1,020	3.0
Pulp press water	150	1,710	420	2.6
Pulp silo drainage	175	7,000	270	12.3
Lime cake slurry	75	8,600	120,000	6.5
Lime cake lagoon effluent	63	1,420	450	0.89
Barometric condenser water	1,665	40		0.67

[1] Water-transported pulp in lieu of mechanical conveyor.

FLUME WATER WASTE

Flume water characteristics are influenced by the type of soil in which the beet is grown, the weather during harvest, and the extent of spoilage in the stockpile. Wet weather during harvest may be expected to increase the quantity of soil carried on the beets.

Suspended solids are most variable, with values as high as 4,300 and as low as 800 ppm having been observed. Flume water BOD normally varies between 150 and 250 ppm, but may triple in concentration when transporting frozen or rotten beets. The volume of flume water at different factories ranges from 1,750 to 2,580 gal. per ton of beets.

PULP SCREEN WATER

Pulp screen water is drained from the pulp through a screen. It is comprised of water contained in each cell when it is isolated from the diffusion circuit for dumping, plus water used to flush out the cells, and in certain cases, water added to create a pulp suspension for pumping to the screen. It contains finely divided pulp in suspension, organic material in colloidal suspension, and a comparatively large amount of sugar and other organic material in solution. The sucrose content may be expected to vary between 300 and 600 ppm. A small amount of sand from the beets is also present. This waste has a temperature of about 50° C.

The concentration of the waste is dependent to a considerable extent on the type of diffuser and the efficiency of the pulp screen. Diffusers requiring large volumes of wash water give a relatively dilute waste, but the overall pollution load is increased. The BOD varies between 500 and 1,000 ppm, depending on the type of diffuser. The BOD of daily composites may vary as much as 50 per cent from the average. Pulp screen water from one plant with bottom

dump diffuser cells had an average 5-day BOD of 980 ppm following screening through a 30- by 40-mesh vibrating screen (2).

PULP PRESS WATER

At factories where pulp is dried, the screened pulp is further dewatered in presses before drying. Water pressed from the pulp constitutes pulp press water. The characteristics of pulp press water vary with the physical quality of the pulp. They are similar to pulp screen water with somewhat higher solids and BOD. The sucrose content may average as much as 2,100 ppm. Pulp press water amounts to some 150 gal. per ton of beets, with a BOD averaging 1,700 ppm.

PULP SILO DRAINAGE

Pulp silo liquor drains from wet pulp during storage in open silos. The volume varies with the quantity of pulp stored, efficiency of the pulp screen, fermentation, and rainfall. The volume per ton of beets at two factories averaged 138 and 225 gal., respectively. Daily flow varied as much as 30 per cent from these average values. The BOD of these same wastes averaged 8,800 and 6,000 ppm, respectively, with daily composites varying as much as 50 per cent from the averages. Organic acids of decomposition create a pH of about 4 in this waste.

Pulp silo drainage is the one waste which does not cease at the end of factory operation. In fact, it may become more concentrated if pulp remains in the silo until warm weather. Data given in Table I for silo drainage are for the period the factories were operating (2).

LIME CAKE SLURRY

Lime cake forms when lime-treated and carbonated juice is filtered. It is common practice to dilute the cake with water to form a slurry which can be pumped. The amount of water added to the cake is dependent to some extent on

the type of filter and the operator. These factors must be considered in comparing volumes and concentrations of the waste. Lime cake waste has been reported to range from 6,850 to 10,250 ppm BOD and from 107,000 to 137,000 ppm suspended solids. The pH of the waste is about 11.7.

Available data indicate Steffen house lime cake slurry to have a somewhat higher BOD value per ton of beets than for a straight house. This suggests materials return with the saccharate from the Steffen process which are removed in the lime cake. Accepting this premise, it will be evident that lime cake waste from a Steffen house will be influenced by the amount of molasses worked.

STEFFEN WASTE

The filtrate produced in filtering saccharate cake from lime-treated diluted molasses in the Steffen process is known as "Steffen Waste." Because Steffen plants process varying amounts of foreign molasses in addition to their own, it is desirable to express Steffen waste on the basis of molasses worked. Steffen waste is reasonably uniform in volume and concentration, as will be appreciated from the following considerations.

Beet sugar molasses contains 60 to 63 per cent sucrose (sugar), dry solids basis. This relation between sugars and non-sugars holds whether the molasses is produced in a straight house or a Steffen plant. On a total weight basis, molasses is about 50 per cent sucrose. It is customary in the industry to convert molasses to a 50 per cent sucrose basis, which likewise reduces the non-sugars to a common basis.

In Steffen house operation, the calcium saccharate returned to process carries with it inseparable non-sugars. These non-sugars tend to accumulate in the Steffen house molasses and, if not eliminated from the system, eventually interfere with sugar crystallization and refining. A fair degree of uniformity

in molasses worked by the Steffen process is achieved by correlating the amount of foreign molasses intake with Steffen molasses marketed.

Approximately 11 tons (2,200 gal.) of Steffen waste are produced for each ton of molasses worked. The pH may be as high as 12.6. Data in Table II apply to Steffen plants employing the combination, cold and h t, saccharate process.

TABLE II. Steffen Waste Character and Volume

Flow, per Ton of Molasses[1] Processed (gal.)	B.O.D. 5-Day 20° C. (ppm)	Total Sol. (ppm)	Susp. Sol. (ppm)	5-Day B.O.D. per Ton of Molasses Worked (lb.)
2,200	10,500	25,000 - 40,000	100 - 700	231

[1] Converted to 50 per cent sucrose (sugar) basis.

BAROMETRIC CONDENSER WATER

Barometric condenser water comes from the multiple-effect evaporators and vacuum pans. This waste is comparable to flume water in volume, but is relatively low in pollutional material. Entrainment from the last effect varies with evaporator design and operation. Evaporator condensates not re-used in process and heated water from other sources may be discharged along with barometric condenser water. Evaporation of Steffen waste produces additional condenser water.

MISCELLANEOUS WASTES

Other wastes of a comparatively minor nature are those from washing filter cloths, equipment, and floors, and from the testing and control laboratory. Sanitary sewage should be separated from process wastes.

POLLUTIONAL EFFECTS

Liquid wastes from manufacture of beet sugar are similar to those from other food processing industries. Oxygen depletion and sludge deposits are common damages to the receiving waters. Destruction o normal aquatic life and severe odor nuisances have resulted from promiscuous discharge of these wastes. The high lime content of be sugar wastes may impart suf cient hardness to the receiving water to be detrimental to its subsequent use. Relatively high-temperature waste, such as ba ric condenser water, may raise the temperature of the stream thereby decrea ng its oxygen carrying capacity as well as encouraging growth of "sewage fungus."

WASTE REDUCTION

A detailed discussion of remedial measures within the plant is beyond the scope of thi paper. However, recent successful developments in Canada and the United States are considered worthy of mention inasmuch as they have direct bearing on the waste cont l-pollu ion abatement program of the industry.

PRESS AND PULP SCREEN WATER RETURN

Hrudka has demonstrated he feasibility of returning untreated press water directly to a continuous diffuser at Chatham, Ontario (3). Acid conditions in the middle cells of the diffuser were controlled by intermittent addition of formaldehyde to the press wate return tank. Temperature in the diffuser water supply tank averaged 55° C. with a maximum of 65° C. Benefits derived from this practice have been substantiated by operation data. Press water reuse is practiced by at least two beet sugar plants in the States; one employs elevated temperature and the other chlorination for bacterial control (1). In addition, combined press and pulp screen water are reported chlorinated and reused at three plants in the States.

STEFFEN WASTE RECOVERY

Steffen waste is concentrated in multiple effect evaporators in at least one plant in the States (4). The syrup is mixed with and dried on beet pulp thereby enhancing its value as stock food. This recovery process has been reported economically sound. End liquor from production of monosodium glutamate can be recovered in like manner. Steffen waste will continue a problem until such time as adequate evaporator capacity is provided.

INDIVIDUAL WASTE TREATMENT

It is frequently desirable to treat major process wastes separately. This procedure permits step-wise reduction of the pollution load and possesses the inherent advantage of working with a minimum volume. Temporary storage may be indicated because seasonal operation causes overhead to be costly for treatment of the wastes as produced.

FLUME WATER

Treatment consists of screening, grit removal, sedimentation with or without coagulants in tanks equipped for continuous sludge removal, and either vacuum filters or sludge ponds. A retention of 80 min. in the sedimentation basin has been recommended. Removals by this treatment have been reported as high as 92 per cent suspended solids and 42 per cent 5-day BOD (5). Steffen waste has been reported satisfactory as a coagulant for flume water.

LIME CAKE SLURRY

This waste is commonly stored in ponds providing several days retention. Such treatment removes practically all of the suspended solids and gives a substantial reduction of BOD. The volume of this waste is such that lagooning for the entire season is feasible.

PULP SCREEN WATER AND PULP PRESS WATER

Even though re-use of this process waste as diffusion battery water supply should be generally accepted, such a process modification will be gradual in the industry and these wastes must be reckoned with in the interim. Fine screening materially reduces the concentration of these wastes and yields quantities of pulp having economic significance. Vibrating screens (30- by 40-mesh) have been successfully employed. This type of screen has a capacity for screening 22 gal. per square foot per minute of these wastes.

Coagulation of pulp screen and pulp press water with lime has been practiced, using a dosage of 500 to 600 ppm CaO. Lime treatment requires a chemical feeder, mixing chamber, coagulation tank, sedimentation basin, and sludge disposal facilities. Coagulation for 20 to 30 min. and a settling period of 2 hr. have been recommended. Such treatment produces a water-clear effluent and BOD reductions as high as 47 per cent are reported. Other studies have shown as low as 30 per cent average 5-day BOD reduction for lime treatment. In any event, the effluent is still highly objectionable, in that the BOD remaining is high and the treated waste is caustic.

COMBINED PROCESS WASTES TREATMENT

It is not uncommon that waste reduction requirements dictate some degree of treatment for each of the principal wastes. Under these conditions, combining the wastes for treatment rather than separate handling may well prove to be the most economical procedure and frequently it will be the most convenient. Recent beet sugar waste treatment studies in the States have included lagooning and broad field application, both on plant scale. Biological filters have proven satisfactory on pilot plant scale in Great Britain.

LAGOON DISPOSAL

Disposal of beet sugar wastes by the lagoon method has been practiced for years as a pollution abatement measure. The system has been recognized as a means of removing settleable solids and of permitting controlled release when there was adequate dilution. This method has been employed with limited knowledge of factors influencing natural purification and the degree of stabilization realized during storage.

The Minnesota Department of Health, Division of Water Pollution Control recently completed a comprehensive study of beet sugar waste disposal by lagooning (6). This investigational research was conducted in cooperation with the American Crystal Sugar Company at the Moorhead, Minnesota plant during and following the 1949, 1950, and 1951 seasons. The member states of the Missouri River Basin Sanitation Agreement and the Public Health Service were co-sponsors of the project. The most extensive waste studies were made during the 1950 campaign with the 1949 work being essentially exploratory and the 1951 work largely confirmatory.

The Moorhead plant, with a rated capacity of 2880 tons of sugar beets per day, was placed in operation in 1948. This is a strictly modern refinery with a 21-cell continuous counterflow diffuser. Three waste disposal lagoons were provided. Two of these, designated "South" and "North" lagoons, are of the same size. They have a total area of 81 acres and a combined capacity of 279 million gallons when filled to a depth of 12 feet. The third is a reserve, shallow lagoon with an area of 50 acres and a capacity of 41.5 million gallons. Discharge from the lagoons is through a county ditch to the Red River of the North.

During 79 days of the 1950 season, these disposal lagoons received 352 million gallons (MG) of waste. This was composed of 337 MG flume water and 15 MG from the pulp presses. An additional 11.6 MG pulp press water were used to flume lime cake slurry to a separate lime disposal pond. These waste volumes give unit values of 1425 gallons flume water and 112 gallons pulp press water per ton of beets sliced.

Daily composite samples throughout the 1950 campaign were analyzed from the pulp press water and the combined flume and press water as discharged to the lagoons. The waste in the south lagoon was sampled every second or third day during the 1950 season and monthly thereafter until the ice break-up in April 1951. In addition to sanitary analyses of the wastes, laboratory experiments were conducted with c alysis, pH adjustment, freezing, and extended storage.

There was a significant progressive increase in biochemical oxygen demand (B.O.D.) concentration of the waste discharged to the lagoons as the season continued. During the first twenty days of the campaign, the 5-day B.O.D. of this waste averaged 3.97 lbs./ton of beets sliced; this unit value increased to an average of 9.37 lbs. during the last twenty days of the season. Total and suspended solids also increased but to a l sser degree. Pulp press water B.O.D. remained relatively constant throughout the season. This increase in B.O.D. in the flume water was attributed to higher losses of soluble materials, resulting from "bleeding" of the beets, after prolonged storage during cold weather. This raw waste B.O.D. increase was reflected in the lagooned waste.

Results of lagoon studies during the 1950 campaign indicated that 53 per cent of the 5-day B.O.D., 87 per cent of the total solids, and 97 per cent of

the suspended solids were removed from the wastes by lagooning. Removal of B.O.D. varied from 58 per cent during the first quarter of the season to 48 per cent for the last quarter. This decrease in efficiency toward the end of the season was associated with increase in the ratio of soluble to non-soluble constituents in the raw wastes and the inhibiting effect of lower temperatures on any biological oxidation that may have been occurring.

The data revealed that at any time during the campaign the amount of 5-day B.O.D. remaining in the lagoons was approximately half the amount that had been added. During the winter storage period, no material change was detected in the total quantities of 5-day B.O.D., total solids, and chemical oxygen demand (C.O.D.) in the lagoon. Apparent increases in the measured concentrations of these constituents were offset when corrections were made for ice cover. There appeared to be little or no biological activity effective in reducing the concentration of the waste at the near or below freezing temperatures in these lagoons. It was concluded from this work that lagoon treatment of beet sugar wastes, at this latitude, could be expected to give very efficient removal of suspended solids and approximately 50 per cent reduction in 5-day B.O.D.

Bottle studies were conducted on lagooned waste collected beneath the ice. Samples incubated for 90 days at 2°C. showed no reduction in 5-day B.O.D. which confirmed field observations. Portions of the same waste samples incubated for 90 days at 20°C. were reduced 56 per cent in 5-day B.O.D. These results demonstrated the influence of temperature on biological activity and indicated what might be expected when organic wastes are lagooned in milder climates.

BROAD FIELD APPLICATION

European practice in beet sugar waste treatment was investigated by a representative of The Great Western Sugar Company in the fall of 1950. This was one phase of review of the technology of beet sugar manufacture at several plants visited in England and on the Continent. Observations at Elsdorf, Germany indicated satisfactory treatment for flume water and lime cake slurry by means of a series of shallow desilting ponds followed by flow over grassy plots. A new plot was placed in service each hour in order not to drown out the grass, sufficient plots being provided to permit rotation. The Elsdorf treatment system was reported to reduce the 5-day B.O.D. to 15 ppm.

Based on these observations, The Great Western Sugar Company conducted large scale waste treatment studies at the Loveland, Colorado Steffen House beet sugar factory during the 1951 season. Two grassy plots, each 75 feet wide by 1100 feet long, were used in conjunction with a settling pond. One plot received settled waste at the rate of 1 cfs and the other at a rate of 1/2 cfs. The 5-day B.O.D. of the settled waste was reported as 604 ppm. The effluent from the plot receiving 1/2 cfs had an average 5-day B.O.D. of 416 ppm indicating 31 per cent reduction. Although the results accomplished at Loveland did not approach those reported at Elsdorf, Germany, it was thought that more complete treatment could be realized from improved distribution and other refinements. Accordingly, the company decided to try this system of treatment on plant scale at the Bayard, Nebraska beet sugar refinery.

The Bayard plant is a typical Straight House with a rated capacity of 1850 tons of beets per day. Liquid wastes include flume and beet wash water, pulp screen water, pulp press water, and lime cake slurry. The waste treatment field consists of a rectangular tract of land 1750 feet wide and 3500

feet long. The area was first used for waste treatment during the 1952 campaign. Limited analytical work in the fall of 1952, on the part of the company, showed promising results.

The Public Health Service became interested in the Bayard treatment system as a possible method of beet sugar waste disposal in other areas. This interest led to a cooperative field study at Bayard, Nebraska beginning October 19, 1953 and extending for a period of approximately one month. This investigational research was sponsored and directed by the Missouri Drainage Basin Office, Public Health Service. Cooperating agencies included: The Great Western Sugar Company, and the Nebraska and Wyoming State Health Departments. The U. S. Weather Bureau, U. S. Geological Survey, and the Nebraska Department of Roads and Irrigation gave valuable assistance. Results of this field study are contained in a report dated April 1954 (7).

Process wastes from this plant are discharged through a drainage ditch to the North Platte River. Flow in the ditch during the beet sugar season was reported as 36 cfs and the river discharge at the railroad bridge approximately 2-1/4 miles below Bayard averaged 1220 cfs. During the period of the study, pulp press water was discharged directly to the drainage ditch through a separate sewer. All other process wastes entered a waste canal from which they were pumped to a distribution flume having 4 inch outlet pipes to the field. After flowing across the grassy surface, the waste was collected at the lower end in a canal and discharged to the ditch. Effluent from the treatment plot flowed some 6000 feet to North Platte River.

On a pounds B.O.D. basis, 68 per cent of the wastes produced were applied to the treatment plot, 18 per cent were discharged directly, and the remainder inadvertently reached the ditch untreated. Applied waste had an average 5-

day B.O.D. of 483 ppm while the effluent from the field averaged 158 ppm B.O.D. Waste volume to the field was 4.3 cfs but only 3.5 cfs were discharged from the field; the difference was attributed to seepage and evaporation. The average retention on the field was determined by chloride tests to be 14.5 hours. The B.O.D. removal in ppm was 67 per cent, however, over 73 per cent of the pounds B.O.D. applied remained on the field. Suspended solids removal exceeded 99 per cent.

The grassland field acted primarily as a settling area with supplemental biological oxidation. Settleable solids were removed in the upper quarter of the field coincidentally with 60 per cent reduction of B.O.D. Biological action in the lower three quarters of the plot resulted in an additional 7 per cent B.O.D. removal and about 10 per cent reduction in dissolved solids. The lime slurry may have caused some chemical precipitation of finely divided solids though this action appeared negligible. The area was relatively free from odor. Algal and protozoan growths were present in large numbers but short circuiting and channeling of wastes prevented their full utilization. Improved distribution and leveling should increase the overall efficiency of treatment for this grassland area.

The drainage ditch above the beet sugar plant had an average dissolved oxygen concentration of 9.89 ppm which represented 99 per cent saturation. The treated and untreated beet sugar wastes reduced the D.O. in this ditch water to a minimum of 4.19 ppm. Stream analyses confirmed the degree of treatment observed for the grassland treatment field.

BRITISH RESEARCH

The British Water Pollution Research Laboratory has reported satisfactory pilot plant treatment of lagooned beet sugar wastes by biological filtration (8). Experimental work was performed with recirculated flume water containing about 2 per cent process wastes (pulp screen and press water) at both standard and high-capacity rates. The experimental filter was 12 ft. in diameter and 6 ft. deep.

This experimental work demonstrated that settled flume water was amenable to biological filtration and that this treatment could be relied on to consistentl give a treated waste with a 5-day B.O.D. less than 20 p.p.m. The British concluded from this research that, if settled waste waters were treated continuously throughout the year, a biological filter 60 ft. in diameter and 6 ft. deep should be adequate for treating residual wastes from a factory slicing 2,000 tons of beets per day (9). This system still requires extended storage of a large volume of waste.

SUMMARY

Seasonal operation makes it imperative that capital expenditures for treatment of beet sugar wastes be held to the absolute minimum. This factor places a premium on waste reduction measures and reuse. Application of lagooning and grassland filters must necessarily depend on the degree of treatment required and the availability of suitable areas. In any event, they may be considered expedient measures until reuse of process waters is generally accepted or more satisfactory treatment methods are developed.

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